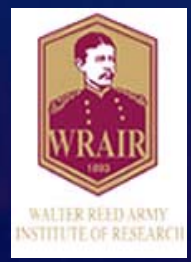
Early Confirmation of Biosensor Detections with Bayesian Fusion of Syndromic Data

Jeffrey S. Lin, Howard S. Burkom, Sean P. Murphy,
Steven M. Babin, Andrew B. Feldman
The Johns Hopkins University Applied Physics Laboratory
Yevgeniy Elbert, Shilpa Hakre
Walter Reed Army Institute for Research

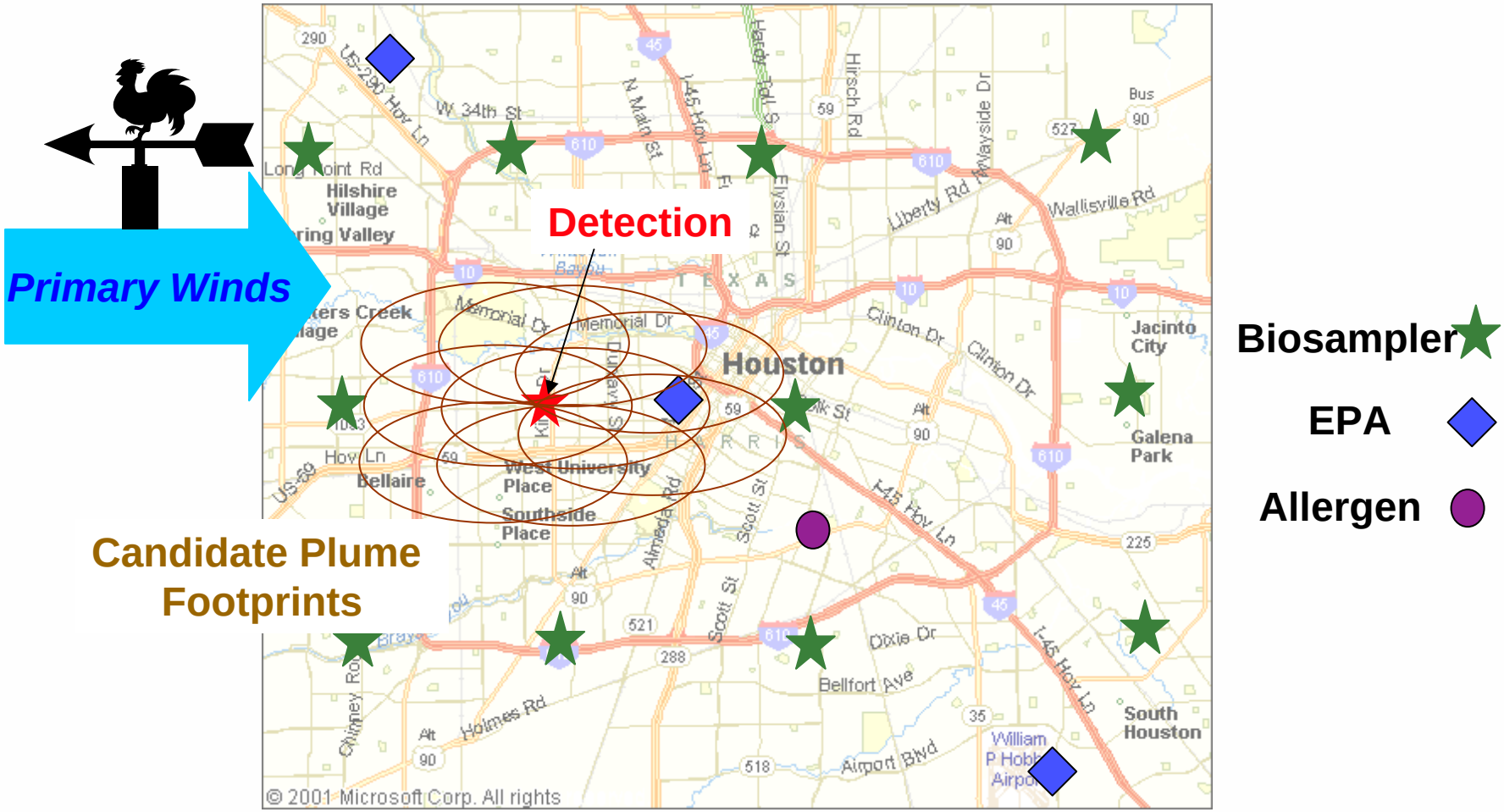


2005 PHIN Conference, May 2005

Goal

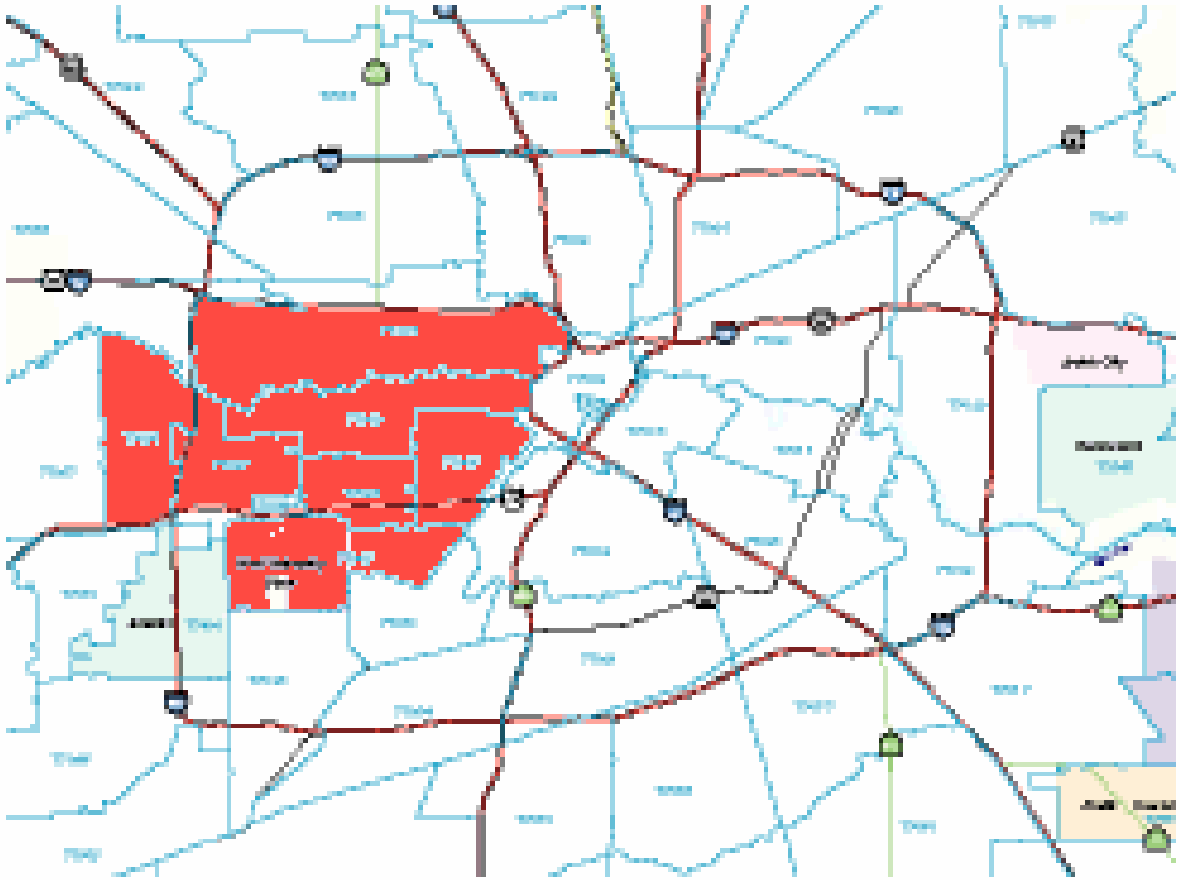
Assist in the coordinated reaction to a bioagent detection by a high confidence bioassay, by providing the earliest possible confirmation that the detected agent poses a public health risk.

Notional Scenario – Meteorological Data and Existing Plume Models



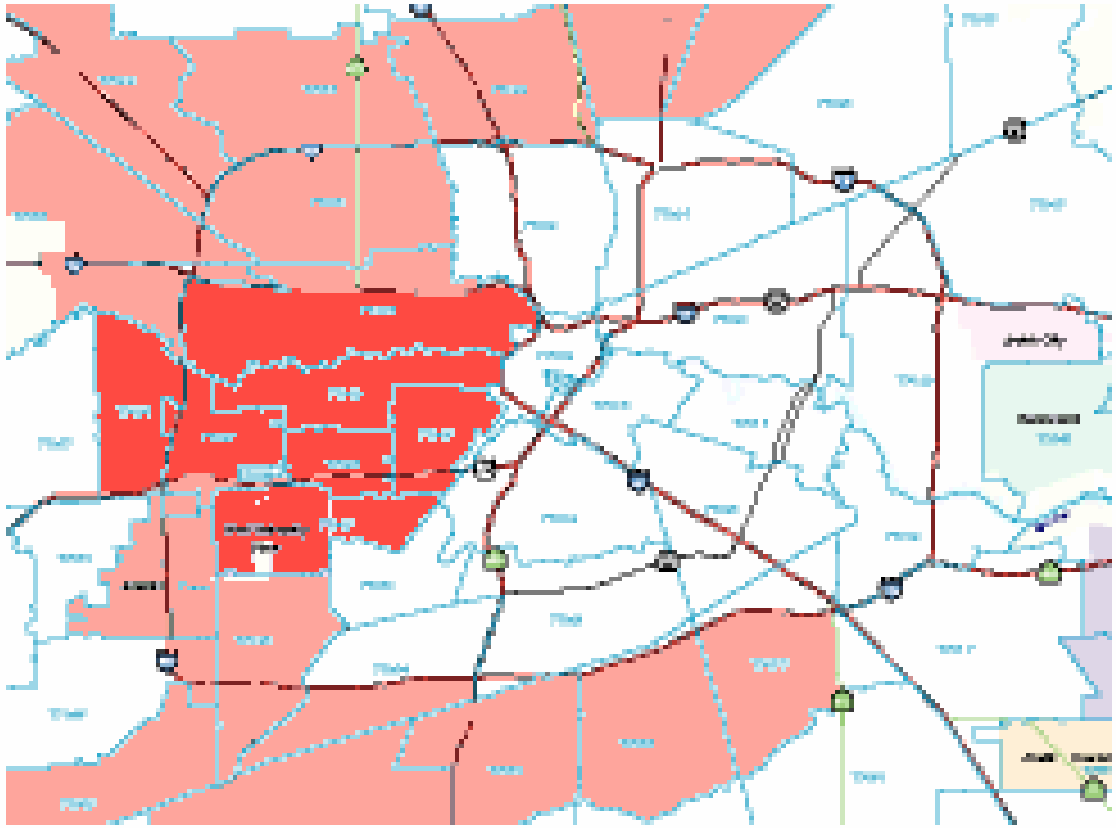
Meteorology and geography of biosamplers constrain source location and plume extent

Notional Scenario – First Order Spatial Aggregation of Syndromic Data



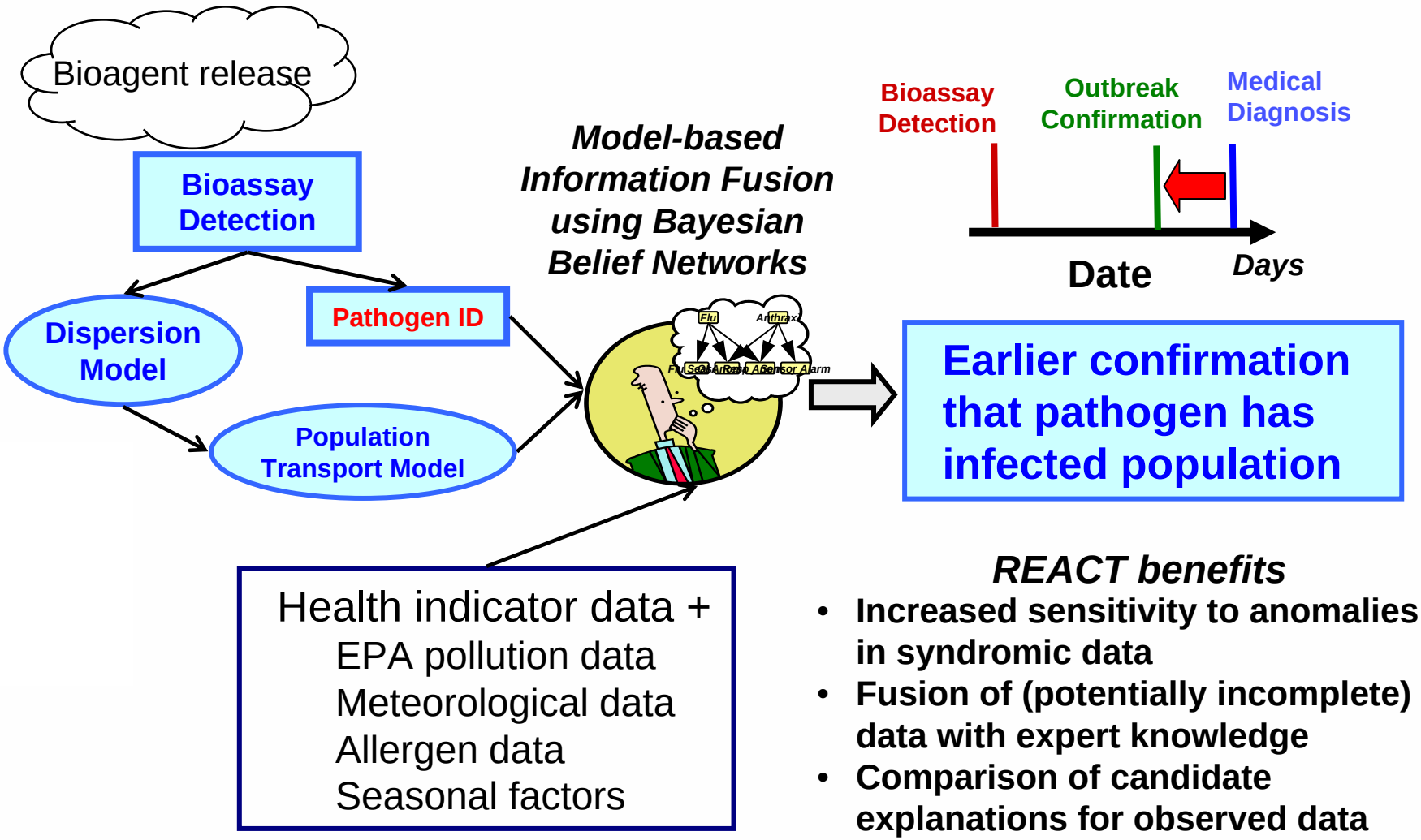
Geographic regions of presumed high risk for increased sensitivity to syndromic anomalies

Notional Scenario – Refinement of Spatial Aggregation with Transportation Models



Geographic regions of presumed high risk for increased sensitivity to syndromic anomalies accounting for commuting patterns

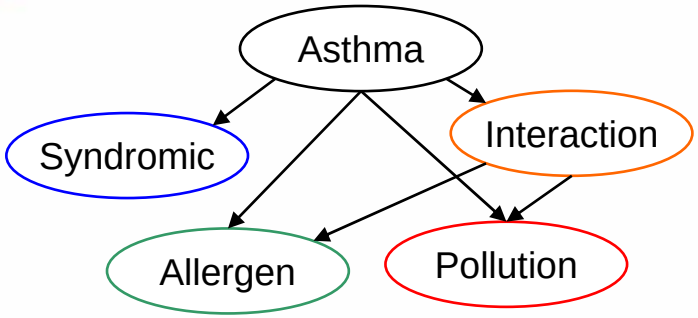
Vision: REACT – Rapid Evaluation and Confirmation of Threats

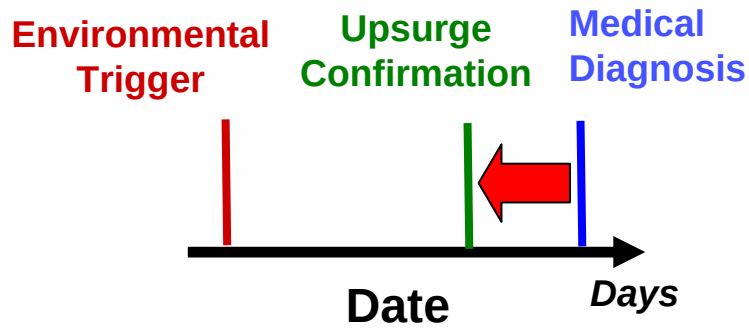


REACT benefits

- **Increased sensitivity to anomalies in syndromic data**
- **Fusion of (potentially incomplete) data with expert knowledge**
- **Comparison of candidate explanations for observed data**

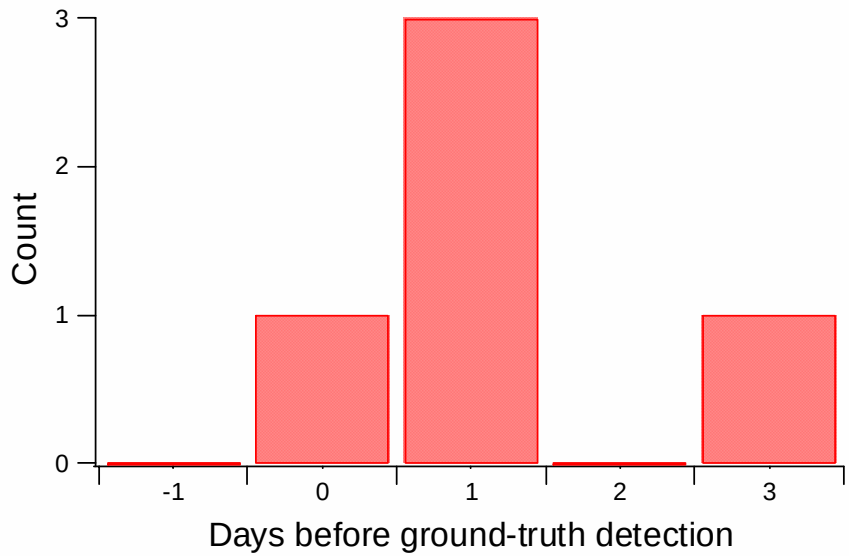
Asthma Case Study





- 2 years from DC Metro area
- 17 asthma upsurges
- 56 sensor alerts
- Sensor performance
  - Detections: 9
  - False alarms: 47
- REACT performance
  - Confirmations: 5 / 9
  - True rejections: 40 / 47
  - False confirms: 7 / 47
  - <1% significance

Histogram of Early Confirmation of Environmental Trigger for Asthma by REACT



Data Fusion Problem Statement

Earlier confirmation of biological attack by fusing all available data, including biosensor and bioassay, syndromic surveillance, environmental, and meteorological data.

<u>Constraints on technical approach</u>

- Limited historical data (“only” a few years at best)
- No historical data for widespread attack
- Data granularity (multiple scales)
  - Endemic diseases
  - Air/Water Pollution
  - Allergens
  - Human behavior

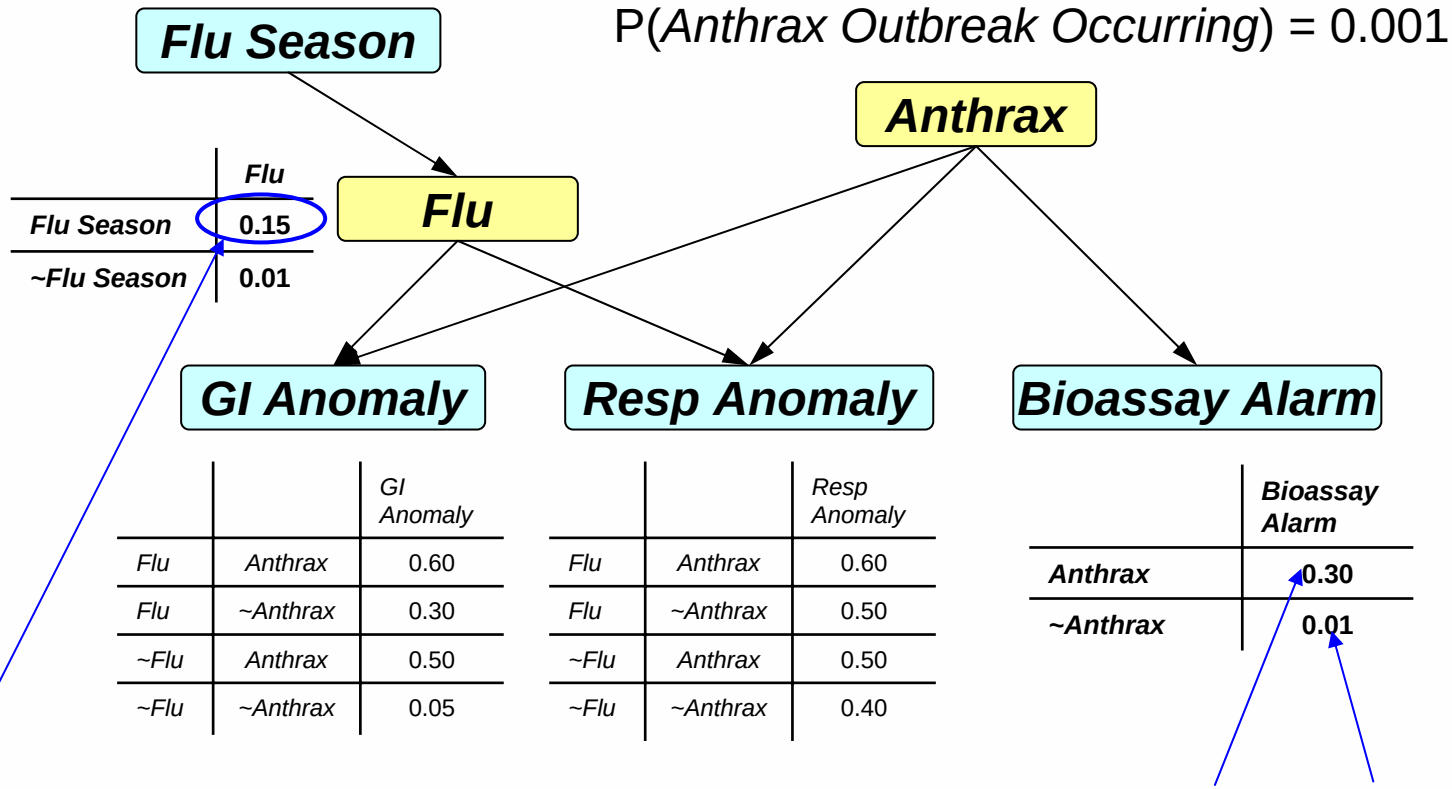
Proposed Solution

- Practical decision support tools (not a “black box”)
  - Encode portions of analyst’s decision process
    - Intuitive computational and data models
    - User can tailor assumptions and models
    - Provide consistent mathematical data fusion framework
- Leverage
  - Historical data
  - Medical and epidemiological literature
  - User’s knowledge and experience
  - Existing meteorological and behavior modeling capabilities

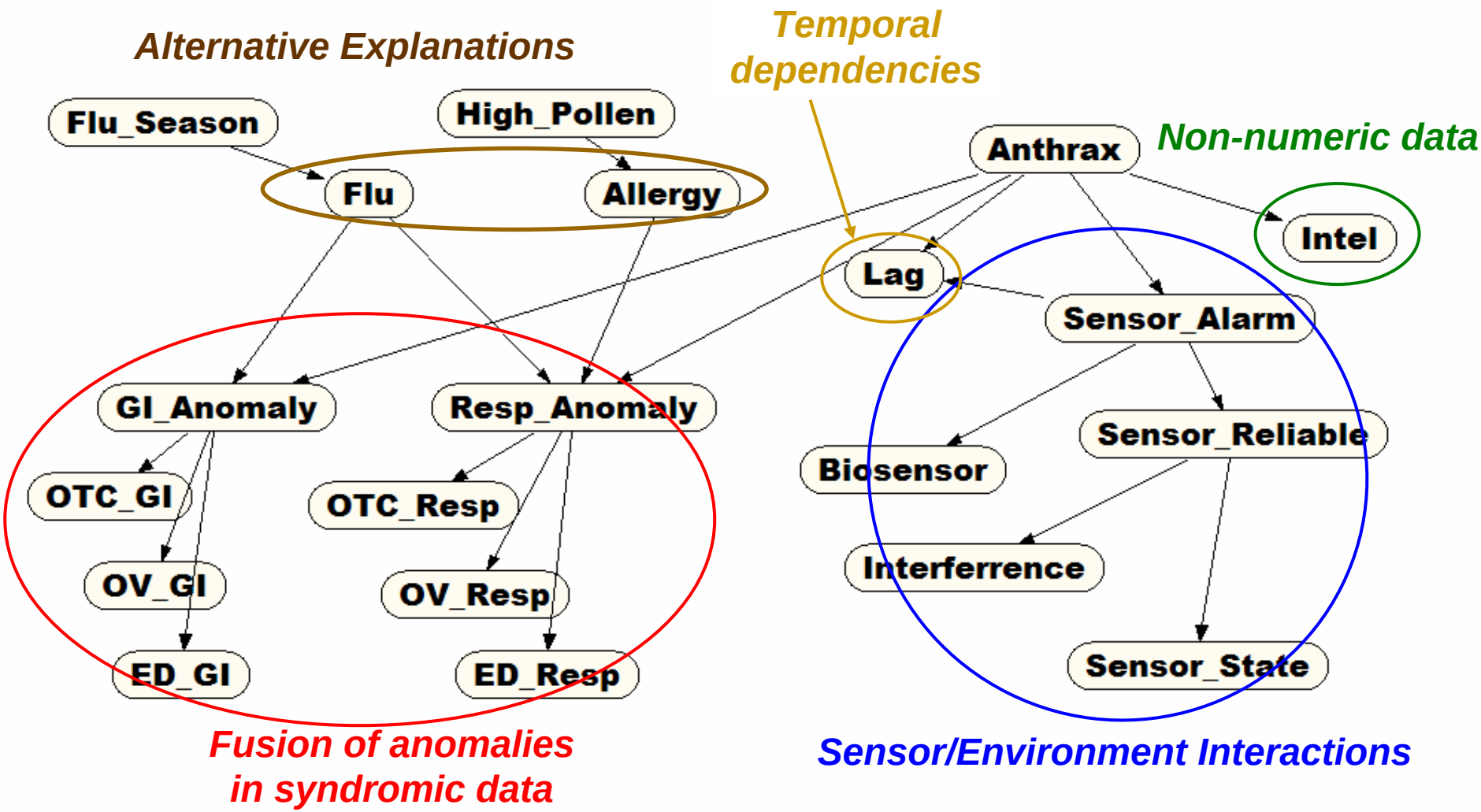
Bayes Belief Networks (BBN)

- Graphical structure for data dependencies
  - Intuitive representation aids design/understanding
- Facilitates fusion of disparate information
  - Continuous/discrete data or derived probabilities
  - Expert/heuristic knowledge
- Modularity in data fusion approach
  - “Plug and play” sub-models possible
- Rigorous management of missing data
- Enables encoding of situational weighting of evidence

Example Bayes Network



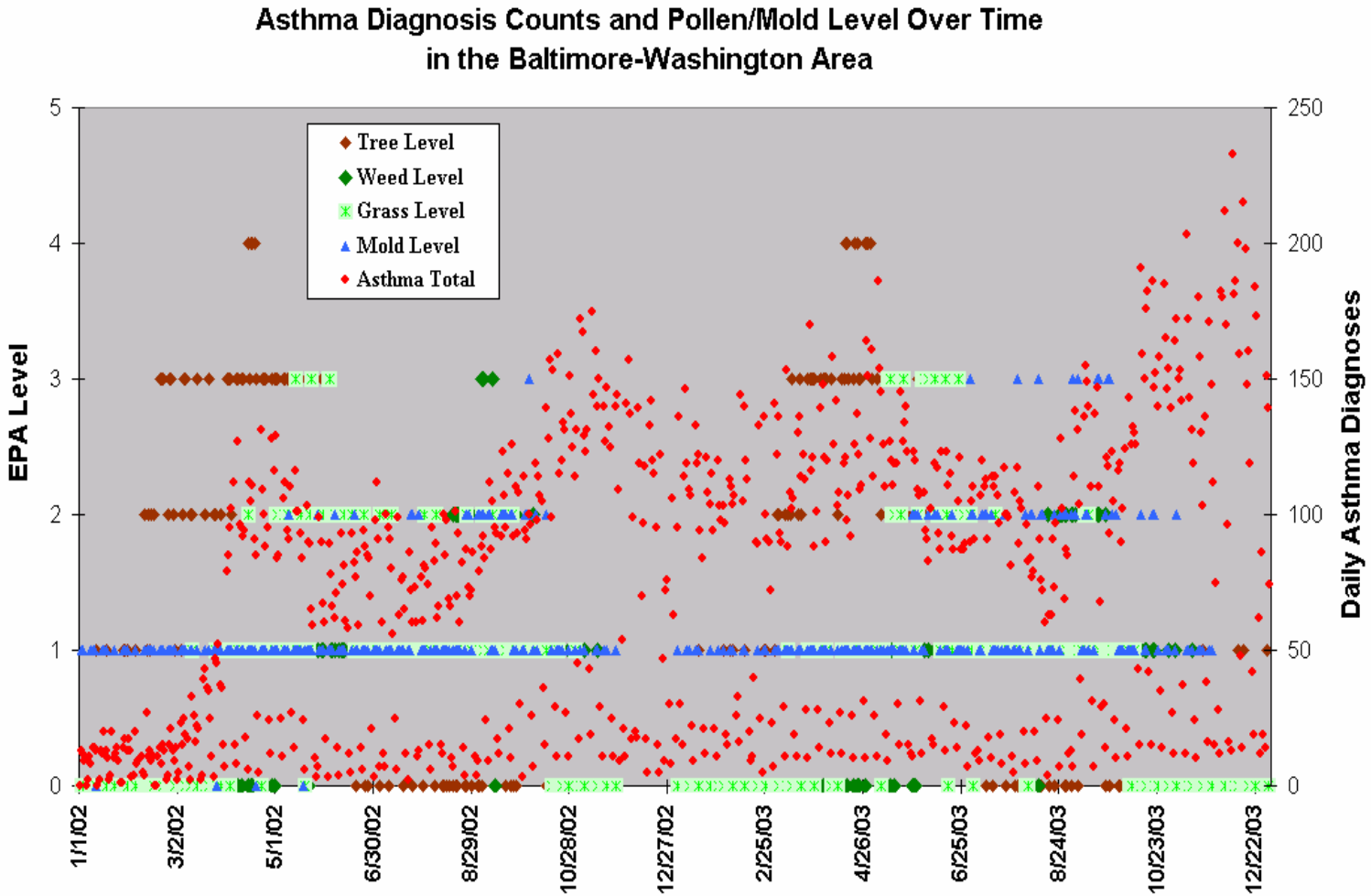
Notional Bayes Network for Event Classification



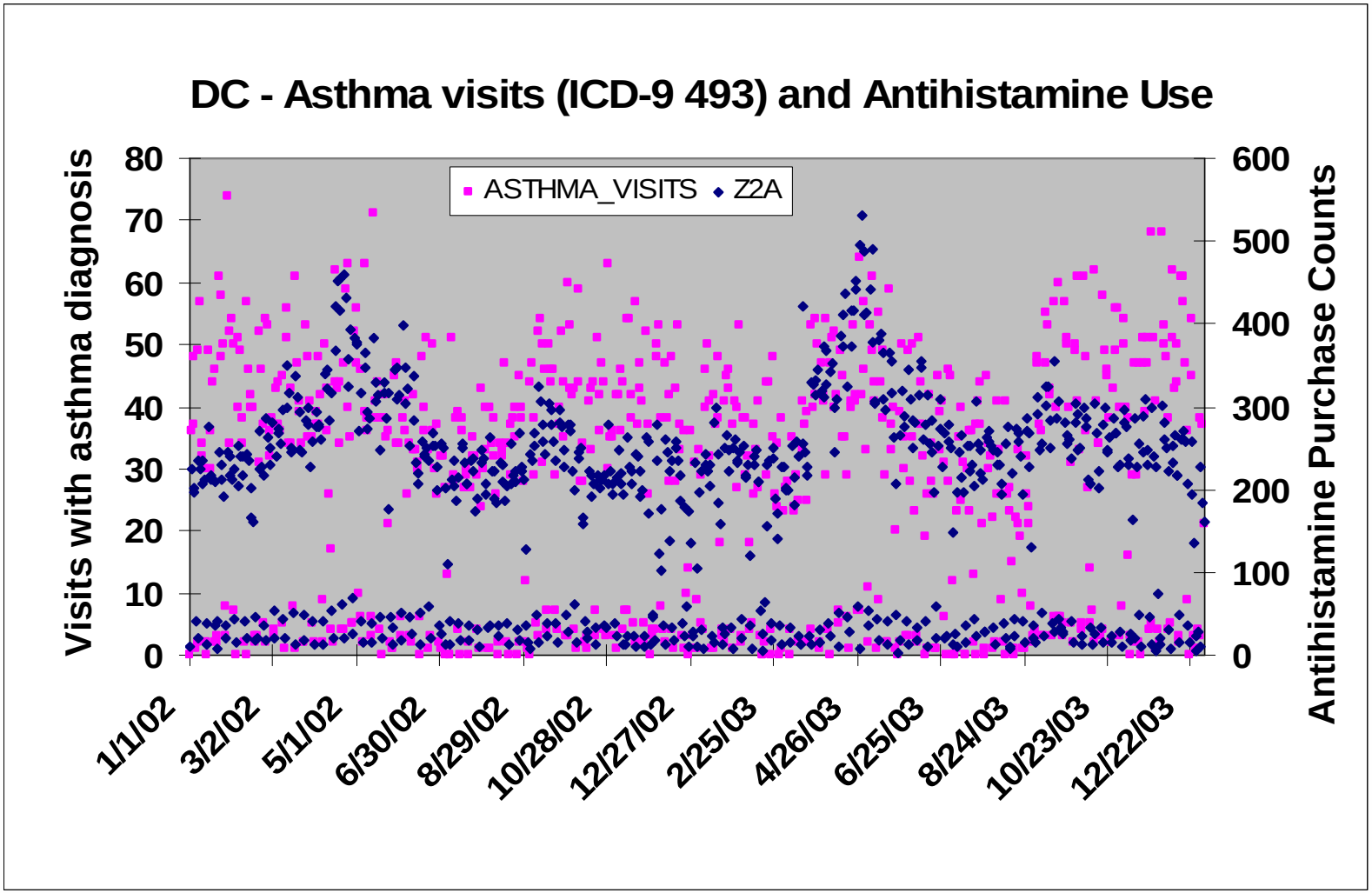
Does it work?- Validation with Asthma Flare-ups

- Availability of practical, verifiable data:
  - “Truth data” – ICD-9 counts
  - “Evidence” – daily environmental, syndromic data
- Asthma triggers
  - Air quality (EPA data)
    - Concentration of particulate matter, allergens
    - Ozone levels
  - Temperature (NOAA data)
  - Viral infections (Syndromic data)
- Interaction model
  - Expert knowledge
  - Historical data (literature)

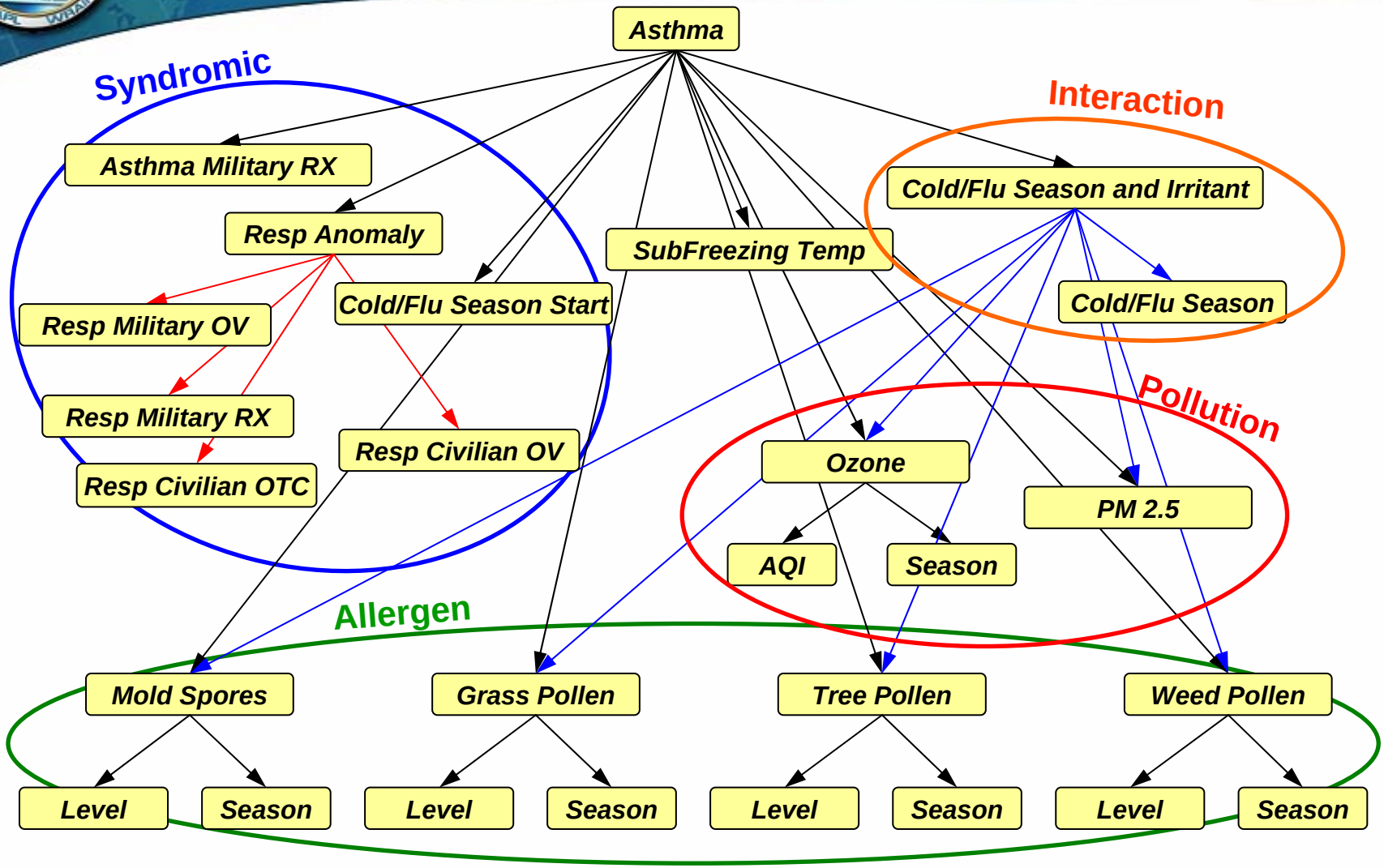
Environmental Evidence: Allergen Levels and Diagnosis Counts



Syndromic Evidence: OTC Sales and Diagnosis Counts



Structure of BBN Model for Asthma Flare Ups

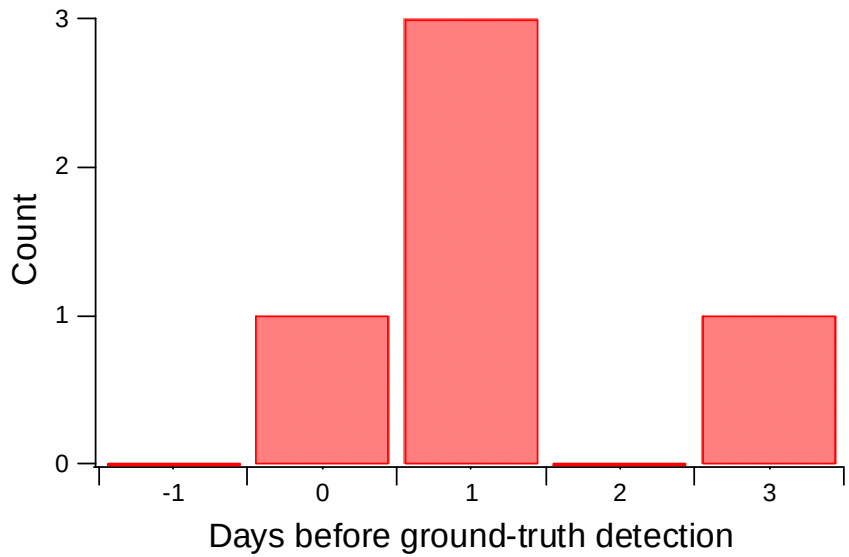


BBN structure and probability tables derived from literature and expert knowledge

Asthma Case Study

- 2 years from DC Metro area
- Military and civilian
- Heuristic network – no training
- 17 asthma upsurges (auto identified)
- 56 sensor alerts
- Sensor performance
  - Detections: 9
  - False alarms: 47
- REACT performance
  - Confirmations: 5 / 9
  - True rejections: 40 / 47
  - False confirms: 7 / 47
  - <1% significance

Histogram of Early Confirmation of Environmental Trigger for Asthma by REACT



All-heuristic BBN performs very well

All bio-terror networks require heuristic parameters

Conclusions from Asthma Validation Study

- BBN modeling “works”
- Untrained heuristic-only BBN add value
  - Training can improve performance if sufficient data exists
- Syndromic data can provide early confirmation of bioassay data